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(54) Title: PROCESS FOR IMPROVING THE TRANSPORTABILITY OF A HEAVY CRUDE OIL

(57) Abstract

A process for improving the transportability of a heavy oil, wherein a part of the heavy oil to be transported is separated out and is degraded to a more liquid substance, which is then mixed with the remaining heavy oil. The separated part of the heavy oil, in mixture with added solid particles and optionally water, is upgraded to a more liquid oil by being cracked in a hammer mill type of apparatus, in which the heat required for the cracking is supplied mechanically. The treated oil, before being mixed with the remaining heavy oil, is subjected to a separation so as to separate out at least a substantial part of its content of solid particles.

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Process for improving the transportability of a heavy crude oil

The present invention relates to a process for improving the transportability of a heavy oil or crude oil, such as a bitumen. Bitumen may have an average molecular weight of several hundreds of grams per mole and is therefore a highly viscous, almost solid material.

A larger part of the world's oil reserves exists as quite heavy oils, such as bitumen. Bitumen fields are often located in remote areas, and transportation of large amounts of bitumen, for instance to a harbour for shipping to a refinery, may be difficult due to the poor transportation properties of the bitumen. In such cases it will be desirable to improve the transportability of the bitumen or heavy oil so as to enable it to be transported through a pipeline without too much difficulty.

Various methods are known in the art for improving the transportability of such oils. One previously known method consists in forming an emulsion of bitumen, water and emulsifier for easy transportation in pipelines and as a ship cargo. This solution has been used for bitumen to be utilized as a fuel in power stations.

Another solution has consisted in improving the transportability of the bitumen by heating the transportation pipeline, for example by providing heat exchangers along the pipeline. This method allows the temperature of the bitumen to be kept higher than the pour point, whereby the bitumen can be more easily pumped and transported through the pipeline. However, the method is expensive and it has the disadvantage that the contents of the pipeline will be prone to solidification under less favourable transportation conditions, and particularly in in the event of a shut off.

It is also known to mix bitumen with a solvent and to transport the mixture in a pipeline from the bitumen field to a

harbour for shipping. Before shipping, the mixture of bitumen and solvent is separated and the solvent is returned to the bitumen field through a separate pipeline.

US Patent No. 4,027,688 describes a method in which a lighter part of a crude oil having poor transportation properties is separated from the crude oil and converted to methanol, which methanol is then mixed with the crude oil to improve the transportation properties thereof. After the transportation of the crude oil, the methanol is separated from the oil, which is an expensive operation, particularly if the methanol must be purified to a marketable grade of purity.

According to US Re. 30281 (originally US Patent 3,910,299), wax-containing hydrocarbon mixtures to be transported in a pipeline are fractionated by distillation into a top fraction and a bottom fraction. The heavy fraction is cooled down until it solidifies to a wax and the light fraction is also subjected to an adapted cooling, whereupon the two fractions are again brought together and mixed to form a slurry of oils and wax particles. The slurry is then transported at a temperature lower than the melting point of the wax. A similar method is proposed in US 3,804,752. It is doubtful that such methods would be useful for such heavy oils as various bitumen grades.

US Patent No. 3,292,647 proposes a treatment of wax-containing crude oils for improving the transportation properties, in which treatment the crude oil is subjected to a shear treatment at a temperature below its pour point in order to break down the wax and form a fine dispersion, whereupon a gas, such as N_2, CO_2 or natural gas, is incorporated into the shear treated crude oil to prevent new growth of the wax crystals during the transportation.

Such known methods consisting in forming finely dispersed suspensions (emulsions) of heavy components in the oil, are sensitive to the transportation conditions. In case of unfavourable transportation conditions and shut offs, one may encounter serious problems of agglomeration and clogging of

the pipeline by the finely dispersed heavier components of the oil.

Thus, there is an obvious need for an improved method for improving the transportability of heavy oils, which is less encumbered with the above mentioned limitations and short-comings.

The present invention now provides a practical and substantially improved process for improving the transportability of a heavy oil, such as a bitumen. In this process, an appropriate part of the heavy oil to be transported is separated out and upgraded to a more liquid oil, consisting for example preponderantly of kerosene and distillate components, by subjecting the heavy oil to a cracking operation under specific conditions in a hammer mill type of apparatus. The upgraded part of the heavy oil is then mixed with the remaining untreated heavy oil to an oil exhibiting desired transportation properties.

To use a hammer mill type of equipment for degradation of hydrocarbons is known per se. US Patent No. 3,282,826 (1966) describes a process for depolymerising bituminous coal and products derived therefrom in a hammer mill, ball mill or similar milling and grinding equipment. In the hammer mill or the like, a solid-solid reaction is carried out between coal particles and the particles of an friable solid metal having a good affinity to oxygen and sulphur atoms. The metal reacts with oxygen and sulphur bridges in the macromolecules of the coal, whereby these molecules are broken down to smaller molecules, with the result that the coal is converted to preponderantly liquid products. The process can be carried out in the presence of a low-viscous solvent and a catalyst may optionally be used for the depolymerization reactions. The milling in the hammer mill or the like generates the required heat for the depolymerization reactions and the process is normally carried out at temperatures below 400 °C and at pressures from 1 to 10 ata. The process requires a pre-drying of the coal to the lowest possible moisture content, as moisture will inter-

fere with the reaction between the metal and the oxygen and sulphur atoms. The metal which is used, and which may be scrap iron powder, aluminum powder or zinc dust, is regenerated for renewed use after having been through the process.

Norwegian Patent No. 175,847 describes a process for selectively and/or unselectively evaporating and/or cleaving liquid hydrocarbon compounds in a hammer mill type of apparatus. In embodiments of the process, a very high specific energy supply can be achieved per unit of area. In addition to bringing about evaporation of the liquid or components of the liquid, said treatment causes, above a given peripheral velocity (page 4, lines 19-20), a decomposition of the hydrocarbons to lighter fractions at ambient temperatures in the reactor up to 50 % lower than the temperatures required in a purely thermal decomposition process. The "thermomechanical decomposition" achieved by the process of the patent is allegedly enabling the process to be used for decomposition of hydrocarbons in petroleum products, so that the process would make possible a direct refining and/or pretreatment of oil or distillation residues from oil refineries.

Norwegian Patent Application No. 943367 describes a process for thermomechanical cracking and hydrogenation of chemical substances such as hydrocarbons. The chemical substances to be treated may be hydrocarbons in liquid or solid form, carbonates, oil shale, oil sand, tar sand, refinery feedstkocks, oil residues from refineries and rest products in crude oil tanks, petroleum residues, plastics and the like, and the treatment may suitably be carried out in a hammer mill. The cracking of the hydrocarbons takes place in a fluidized bed of finely divided solids in the hammer mill and is believed to be induced by local temperature jumps of short duration caused by friction forces between i.a. the fluidized solid particles and the hammers of the hammer mill. The hydrocarbons are thereby heated very quickly to high temperatures suitable for cracking and they are then quickly cooled to the lower ambient temperatures in the hammer mill. Thus, the local cracking reactions have a very short duration.

The present invention now provides a process for improving the transportability of a heavy oil, wherein a part of the heavy oil to be transported is separated out and is degraded to a more liquid substance, which is then mixed with the remaining heavy oil. The process is characterized thereby that the separated part of the heavy oil, in mixture with added solid particles and optionally water, is upgraded to a more liquid oil by being cracked in a hammer mill type of apparatus, in which the heat required for the cracking is supplied mechanically; and the treated oil, before being mixed with the remaining heavy oil, is subjected to a separation so as to separate out at least a substantial part of its content of solid particles.

In preferred embodiments, the cracking is carried out in a hammer mill, at or near the atmospheric pressure, at bulk temperatures in the range of 200 °C to 500 °C, preferably from 250 °C to 400 °C, and with a peripheral speed of the hammers of the hammer mill in the range of 15 to 75 m/s.

The solid particles added to the heavy oil in the process of the invention are primarily mineral particles, such as quarts sand, silica, ceramic particles, aluminosilicates, and the like, but other solid particles, such as metal particles, may be used in specific cases. It has been reported (K. C. Khulbe et al., Fuel Processing Technology 41, 1, 1994) that sand has no catalytic effect in cracking of bitumen. Since no other catalytic materials need be present in the reactor in order to achieve the desired cracking, the process appears to be a temperature controlled process and not a catalytic process.

The presence of water in the process seems to stabilize the process. Therefore, if the separated part of the heavy oil does not already contain water, it is desirable to add water in such quantities that the heavy oil to be treated is given a water content of 1 to 20 % by weight, preferably from 5 to 15 % by weight, calculated on the amount of oil.

It may be advantageous to preheat the heavy oil before it is introduced into the hammer mill.

The process of the invention is described in more detail below with reference to the appended drawings, wherein:

Fig. 1 shows a simplified block diagram of an embodiment of the process of the invention,

Fig. 2 is a perspective view of a hammer mill suitable as a reactor for effecting the process of the invention,

Fig. 3 shows the inner main parts of the hammer mill shown in Fig. 2 and,

Fig. 4 is a diagram showing the results obtained in an example presented below.

In the process plant schematized in Fig. 1, a bitumen having poor transportation properties is introduced at 1 and is preheated in a heat exchanger 2. The bitumen is then mixed in a mixing unit 5 with solid particles, such as sand, supplied via a transportation means 3, and optionally with water supplied via a line 4, whereupon the obtained mixture is introduced via a transportation means 6 into a reactor 7 designed as a hammer mill having a rotating shaft with hammers mounted thereon. Such hammer mills are well known for instance from the mining industry.

The reactor 7 has been started beforehand and has been made ready for the process. This has been effected by supplying sand or other mineral particles to the reactor and putting the shaft with hammers into rotation. The hammers are beating up the sand so that it is dispersed as a fluidized bed along the reactor wall. The friction between the sand and the rotating hammers brings about an increase in the temperature of the fluidized sand bed. When the temperature has reached the desired reaction temperature for the process, the feeding of the mixture of bitumen, sand and optionally water via the transportation means 6 is started. Water which it is desired to add may optionally be added together with the supplied sand by said sand having a desired moisture content. The supplied bitumen mixture is dispersed in the fluidized bed of sand

particles in the reactor 7 and the bitumen is cracked to lighter hydrocarbons.

The reactor 7 may be operated at atmospheric pressure or at a somewhat higher pressure, e.g. at a pressure of up to 10 ata, and at temperatures in the range of 200 °C to 500 °C, preferably in the range of 250 °C to 400 °C. The peripheral speed of the hammers should preferably be in the range of 15 to 75 m/s.

As mentioned, the bitumen mixture supplied to the reactor 7 contains sand, and in step with this supply of sand, sand is withdrawn from the reactor through an outlet 12, so as to maintain a constant level of sand in the reactor. Thus, the added sand will eventually replace the original "starter sand" in the fluidized bed in the reactor.

The cracked bitumen leaves the reactor 7 as a mixture of gas, oil mist and vapor containing minor amounts of sand particles and is passed via a line 8 to a cyclone 9 or other separation means for separation of the sand particles. The separated sand particles may be returned to the mixing unit 5 either directly or via a regeneration unit 13.

The hydrocarbon-containing stream is condensed, either by being passed via a line 20 to the heat exchanger 2, and being used therein to preheat new amounts of supplied bitumen, or in some other cooling means. The condensed hydrocarbon-containing stream is then passed to a storage tank 11.

During the cracking reactions taking place in the reactor 7, the sand particles will be coated by a certain amount of coke and non-vaporized hydrocarbons. The sand particles are withdrawn from the bottom of the reactor 7 and are passed via a line 12 either directly back (not shown) to the mixing unit 5, or to the regeneration unit 13, wherein the coke is burned off in a gas consisting of air, oxygen-enriched air or air diluted with nitrogen. The sand particles, which are now substantially free from carbon deposition, may then be returned to the mixing unit 5 to be mixed with additional amounts of supplied

bitumen. Optionally, the sand particles may be disposed of (15). The heat generated during the coke burning process in the regeneration unit 13 may be utilized to preheat the supplied bitumen, or it can be utilized elsewhere in the process.

As mentioned, the used sand particles that have been treated in the regeneration unit 13 are practically free from hydrocarbons and if they are not to be reused in the process they may be utilized for example as a land fill, in cement production, or in asphalt production. The rest content of hydrocarbons on the sand particles after the treatment is < 500 ppm. Today's strictest maximum limit for admixture with soil (practised by the Netherlands) is 800 ppm.

Fig. 2 is a perspective view of a reactor 20 designed as a hammer mill. The reactor comprises a cylindrical reaction chamber 21 having an inlet 22 for feeding a mixture of heavy oil to be treated, added solid particles and optionally water. The inlet 22 is shown located at the top of the reaction chamber, but other locations are also possible. Solid particles are withdrawn through an outlet 23 located at one end of the reaction chamber 21. Other locations are also possible. Cracked products are withdrawn through an outlet 24, which in the depicted embodiment is located on top of the reaction chamber 21. The reaction chamber 21 may optionally be equipped with inner longitudinal ribs (not visible in Fig. 2). The reactor 20 is further equipped with a through shaft 25 having hammers mounted thereon (not visible in Fig. 2). The shaft 25 is passing through an end part 26 having a bearing 27, at each end of the reaction chamber 21.

Fig. 3 shows the inner main parts in the reactor 20 depicted in Fig. 2, comprising a through shaft 25 having a number of hammers 30. In the depicted embodiment the hammers are assembled in groups of four hammers, so that the hammers of each group extend radially from the shaft 25 as an equal-armed cross. It is to be understood that the number of hammers in each group may vary. In the embodiment shown, having several groups of four assembled hammers, arranged adjacent to one

another along the shaft, the various groups of hammers are not angularly displaced in relation to one another. However, in other embodiments, each group of assembled hammers may be displaced a certain angle, for example 45°, in relation to the preceding group. A circular plate 31 is mounted near the end of the shaft 25, between the outlets 23 and 24 shown in Fig. 2 for solid particles and cracked products, respectively. The plate 31 may be secured either to the shaft 25 or to the reaction chamber 21 (Fig. 2), preferably to the reaction chamber 21. Cracked products pass the plate 31 through a slit between said plate 31 and the shaft 25.

While bitumen has a very high viscosity, typically of an order of magnitude of 1000 cSt at 80 °C, and has a pour point higher than 0 °C, the cracked hydrocarbon product obtained by the process of the invention has excellent flowability, having a viscosity of an order of magnitude of 2-3 cSt at 80 °C, and a pour point lower than -59 °C. The obtained cracked hydrocarbon product is mixed with untreated bitumen having poor transportation properties, in proportions such as to form a mixture having a specified pour point/viscosity enabling effective and secure transportation of the mixture, for example in pipelines to a shipping harbour or a refinery.

The invention is illustrated in the example below.

<u>Example</u>

A bitumen from the Orinoco region in Venezuela, mixed with sand and with 15 % by weight of water, calculated on the amount of bitumen, was cracked in a hammer mill type of reactor, at atmospheric pressure and 305 °C, and at a peripheral speed of the hammers of 35-40 m/s. The bitumen was supplied to the reactor at a rate of about 1 barrel per hour. The cracking required an amperage of about 200 A at a voltage of 480 V, corresponding to an energy requirement of about 95 kWh/barrel, i.e. about 5 % of the calorific value of the bitumen.
The untreated bitumen had the following specifications:

Density (ASTM D-4052)	1.0124 g/l
Viscosity (ASTM D-445)	1004 cSt at 80 °C
Composition (ASTM D-1160):	
light components	0 % by volume
middle distillate	15 % by volume
fuel oil	75 % by volume

The corresponding specifications of the resulting hydrocarbon product were:

Density (ASTM D-4052)	0.8960 g/l
Viscosity (ASTM D-445)	2.62 cSt at 80 °C
Composition (ASTM D-1160):	
light components	0 % by volume
middle distillate	54 % by volume
fuel oil	46 % by volume

In both cases, the "light components" are defined as hydrocarbons having a boiling point < 150 °C, while "middle distillate" is defined as hydrocarbons having a boiling point between 150 and 350 °C, and "fuel oil" is defined as hydrocarbons having a boiling point > 350 °C.

The cracked hydrocarbon product was mixed with varying amounts of untreated bitumen and the viscosity and pour point of the mixture were measured. The results are shown in Fig. 4. It can be seen that addition of even small amounts of the cracked hydrocarbon product to the untreated bitumen results in significant lowering of both viscosity and pour point.

By means of the process of the invention, a desired improvement of the transportation properties of a heavy oil can be obtained without any addition of external solvents or components which do not naturally occur in the heavy oil. This avoids the burden of additional processing steps for separation of such external components, for instance separation of solvents from a treated heavy oil after transportation of the oil in a pipeline from the production field to a shipping harbour and subsequent returning of said external components

to the production field for reuse.

The heavy oil of improved transportability will be stable and relatively insensitive to alterations in the transportation conditions and accidental shut offs. In addition, the cracking of a partial stream of the heavy oil performed by the process of the invention may result in savings in subsequent treatment of the heavy oil, because the need for subsequent cracking will be reduced due to the fact that part of the heavy oil has already been converted to lighter components.

Patent claims

1. A process for improving the transportability of a heavy oil, wherein a part of the heavy oil to be transported is separated out and is degraded to a more liquid substance, which is then mixed with the remaining heavy oil, **characterized** thereby that the separated part of the heavy oil, in mixture with added solid particles and optionally water, is upgraded to a more liquid oil by being cracked in a hammer mill type of apparatus, in which the heat required for the cracking is supplied mechanically, and the treated oil, before being mixed with the remaining heavy oil, is subjected to a separation so as to separate out at least a substantial part of its content of solid particles.

2. A process according to claim 1, **characterized** in that the added solid particles are mineral particles.

3. A process according to claim 2, **characterized** in that sand is used as said mineral particles.

4. A process according to any of claims 1 to 3, **characterized** in that water is supplied to the separated part of the heavy oil prior to the upgrading, so as to provide the oil with a water content of from 1 to 20 % by weight, preferably from 5 to 15 % by weight, calculated on the amount of oil.

5. A process according to any of claims 1 to 4, **characterized** in that the cracking is carried out in a hammer mill, at or near the atmospheric pressure, at bulk temperatures in the range of 200 °C to 500 °C, and with a peripheral speed of the hammers of the hammer mill in the range of 15 to 75 m/s.

6. A process according to claim 5, **characterized** in that the cracking is carried out at bulk temperatures in the range of 250 °C to 400 °C.

7. A process according to any of claims 1 to 6, **characterized** in that the separated part of the heavy oil is preheated before being introduced into the hammer mill.

Fig.1.

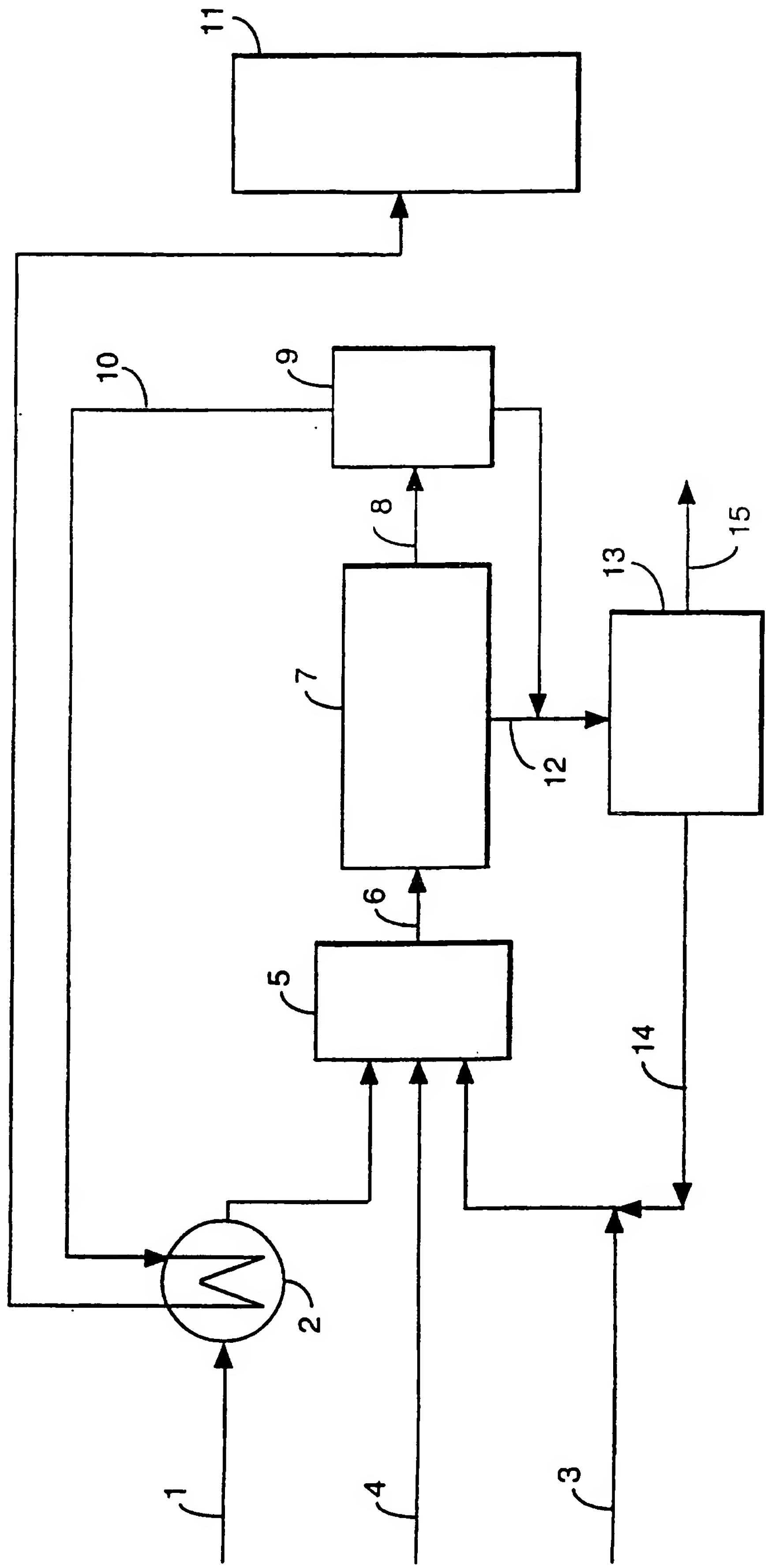


Fig.2.

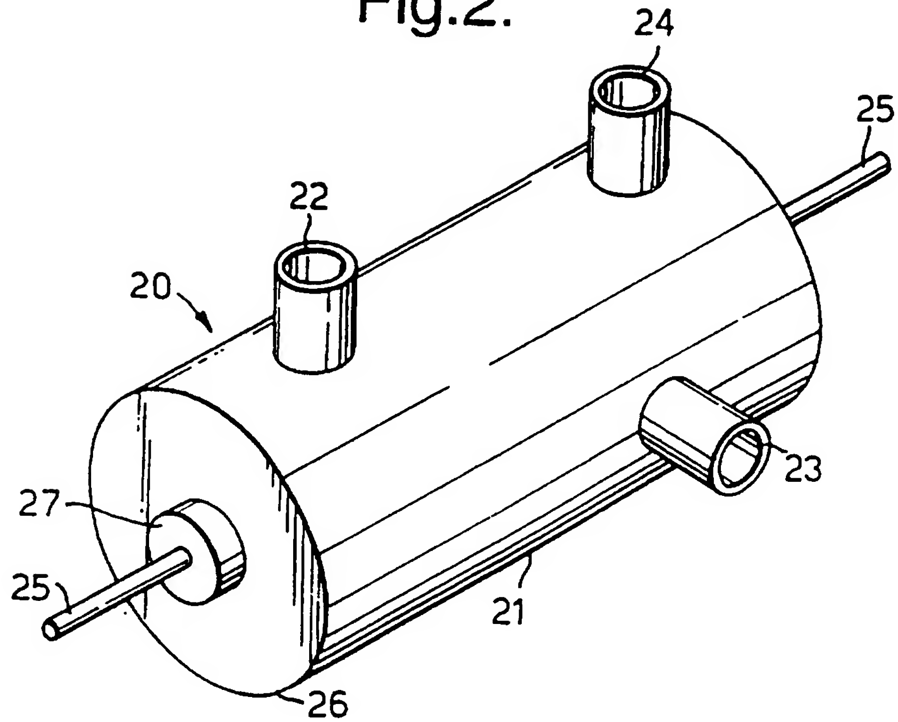


Fig.3.

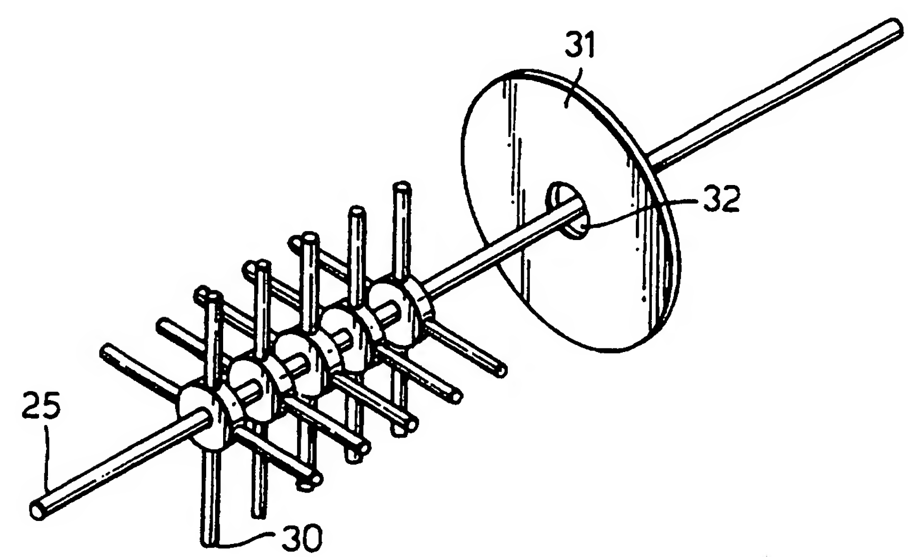
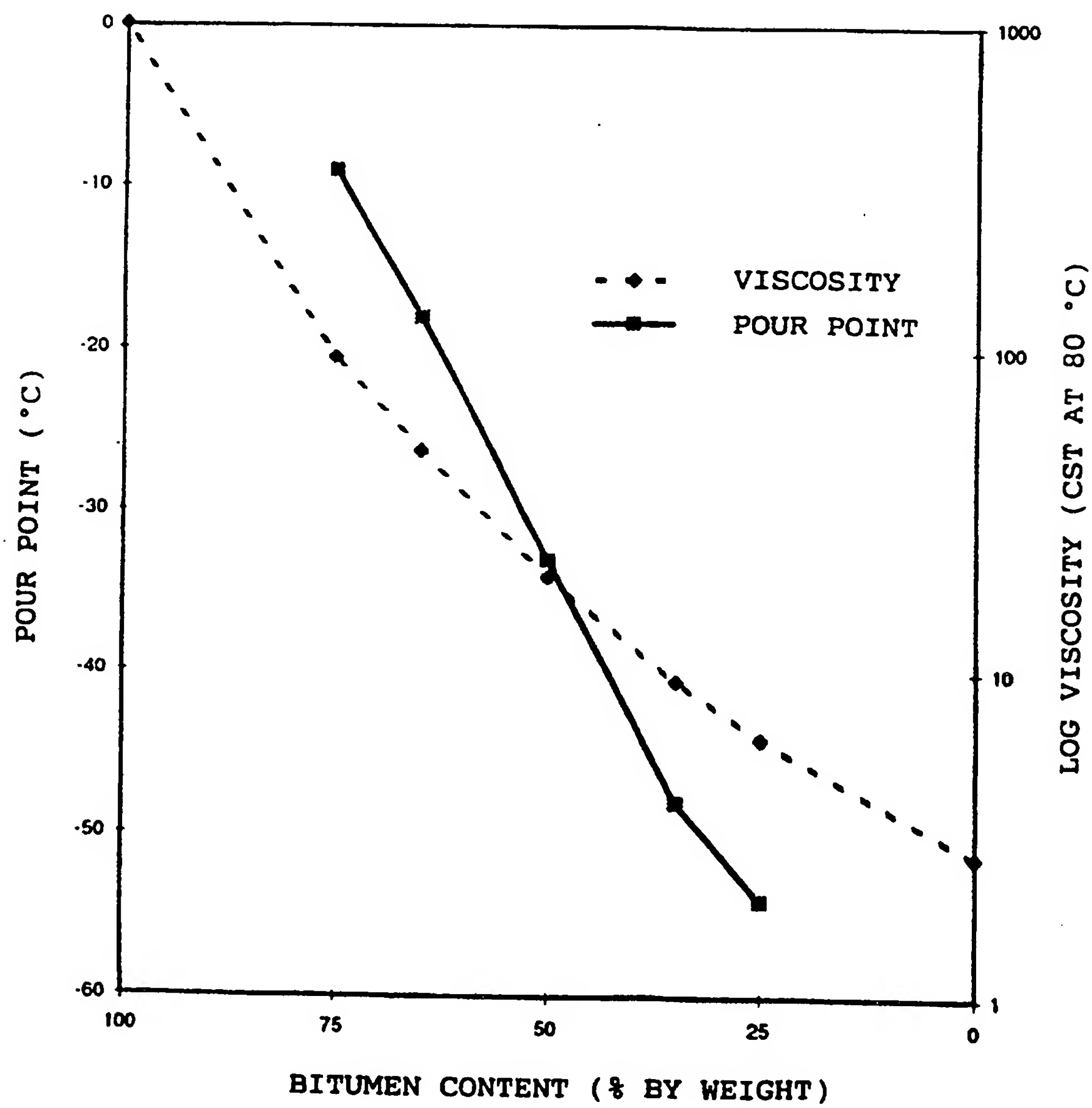


FIG. 4



0
-10
-20
-30
-40
-50
-60
POUR POINT (°C)
1000
100
10
1
LOG VISCOSITY (CST AT 80 °C)
VISCOSITY
POUR POINT
100
75
50
25
0
BITUMEN CONTENT (% BY WEIGHT)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 97/00235

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: C10G 1/00, C10G 9/00, F17D 1/16

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4027688 A (KURT GRUBER ET AL), 7 June 1977 (07.06.77) --	1-7
A	NO 175847 B (OLAV ELLINGSEN), 12 Sept 1994 (12.09.94) --	1-7
A	US 3282826 A (J. WINKLER), 1 November 1966 (01.11.66) --	1-7
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☒ See patent family annex.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

04/11/97

International application No.
PCT/NO 97/00235

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